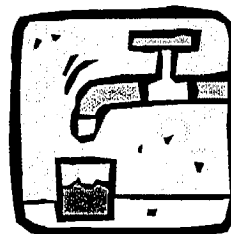


3. DRINKING WATER

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3. DRINKING WATER

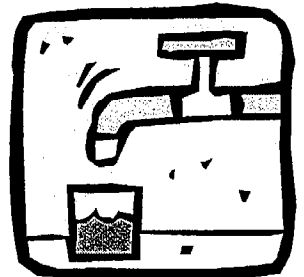
The CALFED drinking water objective is to continuously improve source water quality that allows for municipal water suppliers to deliver safe, reliable, and affordable drinking water that meets and, where feasible, is better than applicable drinking water standards. This section of the Water Quality Program Plan identifies drinking water quality concerns that result from using Delta waters as a source of drinking water supply and identifies proposed Water Quality Program actions that can be taken in the nearer term that may improve source water quality. Bromide, organic carbon, and salts are constituents of major concern for drinking water; salts are of importance to agricultural uses of Delta waters. Concentrations and loadings of these constituents will be affected by actions in the Water Quality Program and by the choice of storage and conveyance options. Section 3.7 presents an analysis of the capacity of Water Quality Program actions to affect concentrations of bromide and organic carbon in drinking water supplies taken from the Delta. Since bromide is a constituent of the total salt load, the analysis in Section 3.7 also can serve as a preliminary model for the effects of the Water Quality Program on total salt in the system.

Bromide, organic carbon, and salts are constituents of major concern for drinking water; salts are of importance to agricultural uses of Delta waters.

3.1 SUMMARY

As part of its commitment to continual improvement of water quality, CALFED is developing an overall Drinking Water Quality Improvement Strategy to guide its activities. The Strategy is composed of a combination of actions and studies that will be conducted under the scrutiny of the Delta Drinking Water Council. Actions and studies include source protection and control, conveyance improvements, storage and operations improvements, monitoring and assessment, treatment studies and facilities, health effects studies, capturing more drinking water during periods of high Delta water quality, and improving the opportunities for voluntary exchanges or purchases of high-quality source waters. This Strategy is critically needed because about two-thirds of Californians drink water that comes from the Delta, and their health can be affected by the quality of that water. Safe drinking water is not a fixed target. Its definition changes continually as new scientific information becomes available, as understanding of water quality and human health impacts improves, and as regulatory developments reflect new scientific findings. The CALFED Drinking Water Quality Improvement Strategy must, therefore, be a continually evolving process to achieve the vision not only of providing drinking water that meets standards for public health protection but also of continually striving toward excellence in drinking water

About two-thirds of Californians drink water that comes from the Delta, and their health can be affected by the quality of that water.



quality. This section identifies the initial features of this Strategy, with the understanding that this constitutes only the beginning of a continuing process. Evolution of the Strategy will be through the full involvement of CALFED agencies, stakeholders, and the public.

Several source water constituents create difficulties for the production of a safe drinking water supply from Delta sources. These include bromide, natural organic matter, microbial pathogens, nutrients, salinity, and turbidity. All are naturally occurring, to one degree or another, and some are magnified by anthropogenic actions. Changes in treating drinking water and reducing sources of contaminants can improve the quality and safety of drinking water from the Delta. Future drinking water regulations may, however, require improvements beyond those that can be gained through the actions specified in this section. (See Section 3.7.) The priority actions listed in the following pages are those that can be implemented in the nearer term with the potential to improve water quality. The degree to which taking these actions may correct the problems is not addressed.

Pollutants in Delta waters come from tidal interaction with the ocean and from point and non-point sources located throughout the Delta and tributary watersheds. Other pollutants can enter the aqueducts and reservoirs of the drinking water supply system. Pathogens largely come from urban stormwater runoff; livestock operations; recreational users of the Delta; storage reservoirs; and, potentially, inadequately treated discharges of wastewater. Sources of organic matter, primarily organic carbon (usually expressed as total organic carbon [TOC]), include runoff from the following sources: soils, agricultural drainage, urban stormwater tidal wetlands as a result of natural plant decay, algae, and wastewater treatment plant discharges. The most important source of bromide is sea-water intrusion, which also is reflected in agricultural drainage from areas irrigated with Delta water. Other sources of bromide may include geological formations, groundwater influenced by ancient sea salts, and use of bromine-containing chemicals in the watersheds of the Delta. Salinity, as reflected in total dissolved solids (TDS), comes from sea-water intrusion and, to a lesser extent, from natural leaching of soils, agricultural drainage, wastewater treatment plants, and stormwater runoff. Turbidity results from storm events, all types of runoff, resuspended sediments, and phytoplankton populations. Nutrients largely result from erosion; agricultural runoff, including livestock operations; urban stormwater runoff; and wastewater treatment plant discharges. Mass loading analyses have not been conducted to establish the relative amounts of pollutants from each of these sources.

Pathogens are a direct health concern. A primary purpose of drinking water treatment is to remove or inactivate pathogens. TOC and bromide react with disinfectants during the treatment process to form disinfection by-products (DBPs) that are a public health concern and will be more stringently regulated in

Pollutants in Delta waters come from tidal interaction with the ocean and from point and non-point sources located throughout the Delta and tributary watersheds.

TOC and bromide react with disinfectants during the treatment process to form disinfection by-products (DBPs) that are a public health concern and will be more stringently regulated in the near future.

the near future. Nutrients contribute to excess growth of algae in storage reservoirs and in aqueducts, which can result in treatment difficulties and production of unpleasant flavors and odors.

High levels of TDS, salinity, and turbidity adversely affect consumer acceptance and treatment plant operations. High TDS reduces the ability to implement local water management programs, such as water recycling and groundwater replenishment, results in direct economic impacts on residential and industrial water users, and reduces options for blending with other supplies.

3.2 DRINKING WATER FOCUS OF THE WATER QUALITY PROGRAM

The Water Quality Program addresses water quality problems exclusive of those that would be addressed by the Storage and Conveyance elements of the CALFED Program. Several drinking water regulations that pose treatment challenges will be implemented and will need to be complied with prior to implementation of storage and conveyance alternatives. Therefore, the primary focus is on water quality improvements in the nearer term, although the Water Quality Program also will be an important aspect of long-term solutions.

Several drinking water regulations that pose treatment challenges will be implemented and will need to be complied with prior to implementation of storage and conveyance alternatives.

CALFED will pursue aggressively a mix of strategies to improve in-Delta water quality. Program actions to address the drinking water concerns of the more than 22 million Californians who rely on Delta water fall into four broad categories. These actions will:

- Enable users to capture more drinking water during periods of high Delta water quality.
- Reduce contaminants and salinity that impair Delta water quality.
- Evaluate alternative approaches to drinking water treatment, to address growing concerns over DBPs and salinity.
- Enable voluntary exchanges or purchases of high-quality source waters for drinking water uses.

None of these actions, by itself, can assure adequate supplies of good-quality drinking water that meet current and future state and federal regulations. All the actions must be pursued in conjunction with other CALFED actions, such as

conveyance and storage improvements, to generate significant improvements in drinking water at the tap.

Both specific and regionwide approaches to drinking water quality improvements address the following locations: the Bay-Delta Region, Sacramento and American Rivers, North Bay Aqueduct, South Bay Aqueduct, Clifton Court Forebay and Bethany Reservoir, Contra Costa Water District intakes, Delta-Mendota Canal (DMC) at the City of Tracy intake, San Joaquin River, California Aqueduct, south of O'Neill Forebay and Check 13, and Castaic Lake and Lake Silverwood.

Priority actions and information needed are identified to ensure that Water Quality Program objectives are achieved in each geographic area.

3.3 PROBLEM STATEMENT

Source water from the Bay-Delta poses treatment challenges and public health concerns for the 22 million Californians who drink the water. Low water quality reduces options for recycling the water and blending with other sources, and increases utility costs of treating the water to meet drinking water regulations and protect public health.

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3.4 OBJECTIVE

The CALFED drinking water quality objective is to continuously improve source water quality that allows for municipal water suppliers to deliver safe, reliable, and affordable drinking water that meets and, where feasible, is better than applicable drinking water standards. This objective promotes improved water management through source control and prevention projects, exchanges, blending, purchases of high-quality water, wastewater recycling, groundwater use, and alternative approaches to drinking water treatment. Of primary importance is the reduction and maintenance of pathogen loadings in source waters to required levels, and the reduction of TOC and bromide levels to avoid production of harmful levels of DBPs. Reduction of TDS will facilitate improved water management.

Of primary importance is the reduction and maintenance of pathogen loadings in source waters to required levels, and the reduction of TOC and bromide levels to avoid production of harmful levels of DBPs.

3.5 PROBLEM DESCRIPTION

Delta waters are used to produce drinking water for approximately 22 million people in California. Utilities divert source water at several points in the Delta, each with distinct water quality characteristics. These waters are subsequently treated by a variety of means to control pathogens and other contaminants of concern, and to meet federal and state drinking water regulatory requirements. Depending on the specific source water at the intakes, existing treatment plant configurations, attendant operational constraints, and regulatory requirements, utilities may have difficulty in simultaneously providing adequate supplies of drinking water while complying with drinking water regulations and meeting customer requirements for palatability. Therefore, two inter-related concerns arise from source water quality: (1) the treated water may not meet all applicable drinking water standards, and (2) the treated water may not be aesthetically acceptable to the consumers. Because treated water quality is a product of source water quality and treatment methods, treatment options can be significantly narrowed based on source water quality and drinking water regulations.

Utilities may have difficulty in simultaneously providing adequate supplies of drinking water while complying with drinking water regulations and meeting customer requirements for palatability.

The process of treating surface waters generally involves mixing coagulant chemicals with the source water. This process causes the removal of some dissolved organic material and most of the particulates to aggregate and to settle out. The settled water is then filtered, usually through beds of special sand and anthracite mixtures, removing many more microbial contaminants. At one or more points in the process, oxidative disinfectant chemicals are applied for specified contact times. Water that flows from the treatment facility into the pipes that distribute the water to homes and businesses must additionally contain a sufficient disinfectant residual (usually chlorine or chloramine) to prevent regrowth of harmful bacteria or other organisms in the distribution system, up to the taps of customers.

The constituents in Delta waters identified of most concern with respect to production of drinking water include microbial pathogens, bromide, natural organic matter, dissolved solids, salinity, turbidity, and nutrients. Some other contaminants of Delta waters, including pesticides, metals, and methyl tert-butyl ether (MTBE), were evaluated and considered to be of limited significance to drinking water at this time because of their relatively low concentrations in Delta waters.

The constituents in Delta waters identified of most concern with respect to production of drinking water include microbial pathogens, bromide, natural organic matter, dissolved solids, salinity, turbidity, and nutrients.

3.5.1 Pathogens

Microbial pathogens are a direct threat to public health. The primary purpose of drinking water treatment is to remove or kill pathogens. Under the 1989 Surface Water Treatment Rule (SWTR), surface water must be treated by filtration or disinfection to minimize disease risks from microbes. In addition, turbidity, which can compromise disinfection, must be removed. Emphasis in this rule was on reducing risks from *Giardia*, *Legionella*, and viruses. The Interim Enhanced Surface Water Treatment Rule was promulgated in December 1998 and adopted more stringent turbidity removal requirements. The Long-Term 2 Enhanced Surface Water Treatment Rule (to be promulgated by May 2002) is expected to include requirements for the control of *Cryptosporidium*.

The primary purpose of drinking water treatment is to remove or kill pathogens.

Filtration and disinfection are required for drinking water from Delta sources. Levels of microbial pathogens in Delta waters do not specifically influence the degree of these treatments, since current regulations are based on uniform treatment requirements. However, future regulations may require treatment that is proportional to pathogen levels in source waters. Pathogen levels in Delta waters are largely unknown at this time. Primary disinfection by utilities using Delta water sources usually is accomplished by physical removal and oxidation with chlorine. An increasing number of utilities are using ozone or a combination of disinfectants.

Chlorine has been used as a primary disinfectant for drinking water for decades. It is effective for bacteria, viruses, and *Giardia* at reasonably feasible concentrations and contact times. It is well understood, relatively simple, and inexpensive. However, it is not able to inactivate *Cryptosporidium*. If future regulations required disinfection of *Cryptosporidium*, alternative disinfectants would be needed.

Chlorine has been used as a primary disinfectant for drinking water for decades.

Some utilities have adopted ozone treatment in addition to other conventional treatment measures. Ozone is a strong oxidant that is effective for inactivation of most pathogenic microorganisms, including *Cryptosporidium*. However, in the presence of bromide such as found in Delta waters, bromate is formed. Bromate is a health concern and is the subject of new drinking water regulations and ongoing health effects research. Optimized conventional filtration is not completely effective to remove all *Cryptosporidium* from drinking water, and chlorinated disinfectants are relatively ineffective in killing or inactivating it. However, membrane filtration, including low-pressure ultrafiltration membranes, does effectively remove *Cryptosporidium* and *Giardia*, and may provide an alternative to additional ozone disinfection. Membrane filtration has been used successfully in small systems, but it is not known whether the technology is adaptable to large systems such as generally are used to treat Delta waters. For this and other reasons, more California water systems are considering converting

Optimized conventional filtration is not completely effective to remove all *Cryptosporidium* from drinking water, and chlorinated disinfectants are relatively ineffective in killing or inactivating it.

to ozone for their primary disinfection. Ozone treatment is also very effective in controlling adverse tastes and odors that are frequently associated with algae in source waters. Other emerging treatment technologies include ultraviolet and chlorine dioxide disinfection, but their potential to produce unwanted chemical byproducts and their economic feasibility are as yet unproven.

3.5.2 Disinfection By-Products

An unfortunate side effect of oxidative disinfection is the formation of unwanted chemical by-products, some of which result in adverse health impacts. Additionally, the objectionable taste and odor (T&O) characteristics of some DBPs affect consumer acceptance. Different oxidants and different sources of water yield different types and concentrations of by-products.

The Safe Drinking Water Act Amendments of 1996 directed EPA to set regulations that protect against microbial pathogens while simultaneously decreasing the occurrence of DBPs. EPA promulgated the first stage of rules (Stage 1 Disinfectants/Disinfection By-Product Rule (D/DBP) and Interim Enhanced Surface Water Treatment Rule) in December 1998. These rules will be effective in December 2001. The Stage 1 D/DBP Rule lowers the maximum contaminant level (MCL) for total trihalomethanes (TTHMs) to 80 ug/l, and sets MCLs for haloacetic acids (60 ug/l) and bromate (10 ug/l). EPA is required to promulgate the Stage 2 D/DBP Rule and Long-Term 2 Enhanced Surface Water Treatment Rule by 2002. These rules currently are being negotiated.

Ozone does not produce halogenated by-products such as chloroform and the other chloro-bromo-THMs, although it produces bromoform and bromate in the presence of organic carbon and bromide. Therefore, ozone use combined with chloramine enables utilities to more easily meet lower TTHM standards. However, ozonation is more complex and expensive than chlorination. Ozonation of natural organic matter generates higher levels of assimilable organic carbon that can support bacterial regrowth in drinking water distribution systems. Because ozonation does not produce a persistent disinfection residual, other disinfectants (generally chloramines) must be used to protect distribution systems from bacterial regrowth and to minimize TTHM formation in the distribution system. Perhaps more importantly, ozone produces chemical by-products of its own. In the presence of bromide, ozone produces bromate, which appears to have the highest cancer-causing potential of the DBPs measured to date. Apart from bromate, ozone has the capacity to produce a number of other oxidized organic by-products, the potentially harmful effects of which are unknown. However, these by-products may be reduced through biological filtration.

An unfortunate side effect of oxidative disinfection is the formation of unwanted chemical by-products, some of which result in adverse health impacts.

Ozonation of natural organic matter generates higher levels of assimilable organic carbon that can support bacterial regrowth in drinking water distribution systems.

Bromide is present in Delta water supplies because of sea-water intrusion into the Delta and agricultural return flows into the San Joaquin River from Delta water. (Bromide in agricultural return flows is primarily due to recycling ocean-derived bromide from areas irrigated with Delta water.) TOC from natural and human sources, and bromide react with disinfectant chemicals to produce a broad range of chemical DBPs with different effects, depending on the disinfectant employed. The presence of bromide in source waters shifts the proportion of bromine-containing DBPs to higher levels. Because of the higher molecular weight of brominated versus chlorinated by-products, it is more difficult for utilities to meet MCLs that are based on weight/volume. Moreover, recent health effects studies suggest that brominated by-products may cause more serious health problems than chloroform, including the possibility of causing miscarriages in pregnant women. In addition, nutrients affect disinfection treatment indirectly by supporting the growth of algae and other organisms, which subsequently adds to the TOC concentrations of the water.

Bromide is present in Delta water supplies because of sea-water intrusion into the Delta and agricultural return flows into the San Joaquin River from Delta water.

3.5.3 Treatment Control of Disinfection By-Products

Currently, most water treatment plants use chlorine as the primary disinfectant within the treatment plant. Many facilities also use chlorine to maintain a disinfectant residual as the water travels through the distribution system. This practice ensures the safety of the treated water as it travels to the consumer but forms elevated levels of chlorinated DBPs.

Chloramines (the combination of chlorine and ammonia) can be used as an alternative to chlorine, to provide a safe disinfectant residual within the distribution system. Chloramines form lower levels of DBPs, replacing the long reaction times between chlorine and DBP precursors in the distribution system. Consequently, this process reduces DBP levels that reach the consumer.

Water utilities also may use “enhanced” coagulation to minimize DBP formation. Enhanced coagulation refers to the practice of using elevated coagulant doses to remove DBP precursors prior to their reaction with chlorine. Under optimal conditions, enhanced coagulation can remove from 30 to 50% of the organic DBP precursors and result in significant DBP reductions. However, the effectiveness of this treatment process is variable and highly depends on raw water quality. In addition, enhanced coagulation does not reduce bromide, which is an inorganic DBP precursor.

Enhanced coagulation refers to the practice of using elevated coagulant doses to remove DBP precursors prior to their reaction with chlorine.

One alternative to the use of chlorine for disinfection is ozone. Ozone is a strong disinfectant capable of inactivating most pathogens within short contact times. The use of ozone also can improve the aesthetic qualities of water, including clarity, taste, and odors. Ozone (in place of chlorine) results in the minimal

formation of chlorinated DBPs. Because ozone does not provide a lasting disinfectant residual, subsequent chlorination (or chloramination) is required—which forms some DBPs. One drawback to the use of ozone is that it reacts with bromide to form bromate. New bromate regulations will take effect in 2001. Previous studies have shown that bromate formation during ozonation may be controlled through chemical addition of acid or ammonia. These bromate control strategies can significantly increase the overall cost of ozonation.

GAC can be used to remove both DBPs and DBP precursors. GAC acts as an adsorbent, removing many organic compounds. Once the GAC adsorption capacity is exhausted, it must be regenerated within a furnace. Typically, GAC must be shipped to an off-site regeneration facility. Consequently, GAC has relatively high capital and operating costs.

GAC has relatively high capital and operating costs.

Recent developments suggest that the use of membrane processes, such as reverse osmosis or nanofiltration, may provide a viable method for controlling DBP precursors. Membranes can remove both organic precursors and the bromide ion, which both contribute to DBP formation. Additionally, these membranes provide excellent pathogen removal. Drawbacks associated with the use of membranes include the need for extensive pre-treatment to minimize membrane fouling and the difficulty in disposing of the brine waste stream (which results from separating the dissolved material from solution). These concerns result in the relatively high current costs for membrane treatment. Other membrane processes such as microfiltration and ultrafiltration provide excellent pathogen removal but do not reduce DBP precursors to a substantial degree. However, as the processes provide increased pathogen removal, they may contribute to decreased disinfection requirements—resulting in less DBP formation.

Recent developments suggest that the use of membrane processes, such as reverse osmosis or nanofiltration, may provide a viable method for controlling DBP precursors.

Recent private-sector efforts have generated substantial advances in treatment technologies. CALFED will encourage these technologies by funding a demonstration project to design and operate an ultra-violet (UV) disinfection plant. CALFED also will fund demonstration projects to design and operate desalination facilities for agricultural drainage, using membrane treatment technology and focusing on management of brines and on-site waste stream management, and other promising treatment technologies that arise during the Program. Specific treatment goals are to:

- Initiate a UV disinfection plant demonstration project by the end of 2002.
- Initiate a regional desalination demonstration project by the end of 2002.
- Evaluate the practicability of and determine time lines for full-scale implementation by the beginning of 2007.